University Microfilms
313 North 1st St
Ann Arbor Michigan

American
POTATO JOURNAL

Volume 36 *March 1959* *Number 3*

CONTENTS

Homemakers' reactions to two specific gravity classes of Russet Burbank potatoes 81
IDA CECIL, ANDREA MACKEY, SUE JOINER AND JOY STOCKMAN

Pseudomonas fluorescens in relation to certain diseases of potato tubers in Maine 90
DONALD FOLSOM AND B. A. FRIEDMAN

A yellow strain of potato virus X 98
A. J. HANSEN AND R. H. LARSON

The influence of specific gravity and chemical composition on hardness of potato tubers after cooking 105
M. K. SHARMA, D. R. ISLEIB, AND S. T. DEXTER

Call for papers for annual meeting 113
R. V. AKELEY

Official Publication of

THE POTATO ASSOCIATION OF AMERICA

NEW BRUNSWICK, NEW JERSEY, U. S. A

THE NEWEST FUNGICIDE FROM DUPONT *for potato growers*

MANZATE®

maneb fungicide

- Controls blights,
- Helps give higher yields, at no increase in net cost

E. I. DuPONT DE NEMOURS & COMPANY (INC.)
Grasselli Chemicals Department, Wilmington 98, Del.

DUPONT
REG. U.S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

American Potato Journal

PUBLISHED BY
THE POTATO ASSOCIATION OF AMERICA
NEW BRUNSWICK, N. J.

EXECUTIVE COMMITTEE

J. C. CAMPBELL, *Editor-in-Chief*
WM. H. MARTIN, *Honorary Editor*
E. S. CLARK, *Associate Editor*

Rutgers University, New Brunswick, New Jersey

W. J. HOOKER, *President* ..... Michigan State University, East Lansing, Mich.
ORRIN C. TURNQUIST, *Vice President* ..... University of Minnesota, St. Paul, Minn.
PAUL J. EASTMAN, *President-Elect* ..... Department of Agriculture, Augusta, Maine
ROBERT V. AKELEY, *Secretary* ..... U. S. Department of Agriculture, Beltsville, Md.
JOHN C. CAMPBELL, *Treasurer* ..... Rutgers University, New Brunswick, N. J.
N. M. PARKS, *Past President* ..... Department of Agriculture, Ottawa, Canada
CHARLES E. CUNNINGHAM, *Director* ..... Red Dot Foods, Inc., Madison, Wis.
D. S. MACLACHLAN, *Director* ..... Department of Agriculture, Ottawa, Canada
E. J. WHEELER, *Director* ..... Michigan State University, East Lansing, Mich.

Price $4.00 per year in North America; $5.00 in other countries.

Not responsible for free replacement of non-delivered or damaged issues after 90 days.

Entered as second class matter at New Brunswick, N. J., March 14, 1942 under Act of March 3, 1879. Accepted for mailing at special rate of postage provided for in section 412, Act of February 28, 1925, authorized on March 14, 1928.

SUSTAINING MEMBERS

STARKS FARMS INC. ..... Route 3, Rhinelander, Wisconsin
BACON BROTHERS ..... 1425 So. Racine Ave., Chicago 8, Illinois
L. L. OLDS SEED CO. ..... Madison, Wisconsin
FRANK L. CLARK, Founder — Clark Seed Farms ..... Richford, New York
RED DOT FOODS, INC. ..... Madison, Wisconsin
ROHM & HAAS COMPANY ..... Philadelphia, Pennsylvania
WISE POTATO CHIP CO. ..... Berwick, Pennsylvania
JOHN BEAN DIVISION, FOOD MACHINERY CORP. ..... Lansing 4, Michigan
S. KENNEDY & SONS, Growers and Shippers of Potatoes and Onions .. Clear Lake, Iowa
AMERICAN AGRICULTURAL CHEMICAL CO. ..... Carteret, New Jersey
LOCKWOOD GRADER CORP. ..... Gering, Nebraska
EDWARD H. ANDERSON & CO. ..... 1425 S. Racine Ave., Chicago, Illinois
E. I. DU PONT DE NEMOURS AND CO. (INC.)
Grasselli Chemicals Dept. ..... Wilmington 98, Delaware

Your fertilizer may be called complete, but . . .

Can you produce top potato yields with N-P-K alone?

Many potato growers have learned from experience that in addition to nitrogen, phosphorus and potash, secondary and trace elements have become vital to successful potato growing.

Take magnesium for example. All plant life needs it. Magnesium is as important to plant life as iron in the blood is to animals. Magnesium is also a "carrier" of phosphorus to the growing and fruiting parts of the plant.

The alarming fact is that soil in virtually all potato-growing areas of the country is seriously short of this essential mineral.

Why potato soils need magnesium

Special soil problems connected with potato growing make magnesium a critical element. Potatoes are usually grown on moderately acid soils inherently low in magnesium.

Magnesium deficiencies aren't visible until the damage is done. In fact, by the time deficiency symptoms appear, you've undoubtedly been paying a heavy penalty in reduced yields and quality for several years. Lack of magnesium lowers yields as much as 100 bushels per acre.

The answer

The most practical and effective answer is the use of a water-soluble magnesium such as double sulphate of potash-magnesia in a mixed fertilizer. This fertilizer ingredient is marketed under the trade name Sul-Po-Mag*.

"Creators of Living Minerals"

Sul-Po-Mag advantages

Sul-Po-Mag provides a water soluble form of magnesium. It is granular . . . stays in the soil longer . . . feeds crops longer. The result is sustained growth over the season to help produce top yields.

Another advantage: Sul-Po-Mag is neutral. You can use it without changing the soil reaction or increasing the danger of scab.

Sul-Po-Mag is low in chlorine. It provides potash in the sulphate form. Experiment Station results prove that sulphate of potash improves the chipping and shipping qualities of potatoes.

This year for better potato-quality and yields buy fertilizer containing Sul-Po-Mag.

For full details on Sul-Po-Mag, fill in the coupon below.

**Trademark, International Minerals & Chemical Corporation*

S·P·M PREMIUM

Quality fertilizer containing a combination of readily available magnesium and sulphate of potash obtained from *Sul·Po·Mag*®
(DOUBLE SULPHATE OF POTASH & MAGNESIUM)

Look for this identifying seal of approval when you buy. It's your assurance of extra-value fertilizer.

INTERNATIONAL MINERALS & CHEM. CORP.
Potash Div., Dept. APJ-12, Skokie, Ill.
Please send me a free copy of your "Magnesium Booklet" which discusses magnesium and Sul-Po-Mag for specific crops.

Name .....
Route .....
Town .....State .....

POTASH DIVISION 12-58R1

INTERNATIONAL MINERALS & CHEMICAL CORPORATION

Administrative Center: Skokie, Illinois

HOMEMAKERS' REACTIONS TO TWO SPECIFIC GRAVITY CLASSES OF RUSSET BURBANK POTATOES[1]

IDA CECIL, ANDREA MACKEY, SUE JOINER AND JOY STOCKMAN[2]

The purpose of this study was to determine consumer response to the cooking qualities of Russet Burbank potatoes of high and low specific gravity. Potatoes representative of Oregon's main growing areas were used.

The Russet Burbank variety, also known as the Netted Gem, is marketed throughout the Nation as a premium quality baker because of its characteristic mealiness. In Oregon markets, however, it is frequently used by consumers for all cooking purposes since Russet Burbanks make up the major store offerings of potatoes for eight to nine months of the year (4).

Data in regard to cooking quality of Russet Burbank potatoes when prepared by various common methods under home conditions are needed to contribute to the overall picture of the culinary performance of this important variety. Baking is but one of the common methods by which potatoes are prepared. A number of reports have indicated that homemakers frequently boil potatoes. In fact, average figures show that baking is less frequently used as a method of preparation in the home than boiling or mashing. Pan frying of raw or cooked potatoes is also done quite frequently (9).

As pointed out by Nylund and Poivan (6), variety has a definite influence on eating and cooking quality. The Russet Burbank can be expected to differ from other varieties. In addition to varietal characteristics, the degree to which specific gravity differences within a variety give an estimate of cooking quality is an important question. The Russet Burbank potato tends to have high specific gravity. The average specific gravity of Oregon's commercially-produced, late-crop Russets during 1957 was 1.092 (5). This is higher than that of most other major varieties. Heinze *et al* (2) reported the specific gravity of six major varieties which were collected in 1948 and 1949 from states that produced approximately two-thirds of the total late crop. Average figures were: Chippewa, 1.073; Green Mountain, 1.088; Irish Cobbler, 1.087; Katahdin, 1.085; Russet Burbank, 1.093; and Triumph, 1.088.

Although studies have been carried out on consumer response to gravity-graded potatoes, most of this work has dealt with varieties of comparatively low average specific gravity. Consumer response to "low" and "high" specific gravity portions of the Russet Burbank crop may be considerably different from consumer response toward a variety of lower average specific gravity. Even when separated into low and high specific gravity groups, the "low" of the Russet potatoes is equivalent to the "high" of many other varieties. In the 1957 season, two-thirds of the Oregon-grown crop of Russet Burbanks fell in the specific gravity classes 1.090, 1.095 and 1.100 (5). In contrast, Smith's study on acceptance of "Bakers," "Boilers" and "Fryers" may be mentioned (8). In this study of the Green Mountain variety, potatoes designated as bakers were those

[1]Accepted for publication July 30, 1958. Technical Paper 1169.

[2]Home Economics Research, Agricultural Experiment Station, Oregon State College, Corvallis, Ore.

having a specific gravity above 1.080; boilers were between 1.070 and 1.080; and fryers were below 1.070. In the 1957 survey previously mentioned, no Russet Burbank potatoes were found having a specific gravity below 1.070.

Homemakers' preferences in regard to potato characteristics have been determined in several areas and for several varieties. According to a nation-wide survey (9) homemakers based their choice of potatoes on outside characteristics and on cooking quality. They wanted a mealy potato that would cook evenly throughout yet not fall apart in the cooking process. Hotchkiss (3) reported that three-fourths of the 3,143 homemakers interviewed in a three-year study of store offerings and consumer buying mentioned mealiness as the cooking quality most desired in potatoes for baking, boiling and mashing. For boiling, a potato that would hold its shape was desired; and for mashing, a potato that cooked evenly without lumps. Other consumer preference studies (1) (7) support these findings, giving appearance, size and cooking qualities as important reasons for choice of purchases. Sogginess was mentioned as a reason for dissatisfaction, together with darkening and hollow heart.

The cooking performance and culinary qualities of high and low specific gravity Russet Burbank potatoes, as determined from response of the consumer panel, will indicate to growers, processors and distributors the value of specific gravity grading of this variety for meeting consumer preferences.

Procedure

The study was planned to obtain unbiased opinions from representative Oregon homemakers regarding the cooking performance and suitability for most common home uses of gravity-graded Russet Burbank potatoes.

Potatoes were brought directly from farm cellars to the laboratory, where they were separated into high and low specific gravity lots, then distributed to homemakers for their evaluation. No information was given the consumer panel concerning the origin or treatment of the potatoes. Each panel member was informed that two eight-pound samples would be sent with an interval of two weeks between the samples. Sixteen-pound samples were supplied to large size families.

Evaluation was requested for three methods of preparation: baking, mashing and boiling. In this way, all households had an opportunity to evaluate potatoes of both low and high specific gravity for three common cooking methods.

To eliminate first-sample bias, half of the households in each population group were first sent high specific gravity potatoes whereas the remaining households first received low specific gravity potatoes. This order was reversed for the second sample.

Potatoes Used in the Study: The samples used were drawn shortly after harvest from commercially-produced late-crop Russet Burbank potatoes in the fall of 1957. Three or four farms in each of Oregon's main growing areas were selected for sampling. Selection was on the basis of information regarding the specific gravity of each farm's potatoes, obtained in a preceding study of the 1957 crop (5). The potatoes were purchased directly from the grower, and shipped immediately to the laboratory.

Because the potatoes had been taken directly from farm cellars, it was desirable to wash and cull them before separation into specific gravity classes. This was done in the laboratory. The potatoes were allowed to dry, and then were separated into specific gravity groups, using the method of brine flotation. Tubers which floated in a brine solution of specific gravity 1.085 were classed as "low" specific gravity. Those that sank to the bottom of a brine solution of specific gravity 1.090 were classed as "high" specific gravity. Following brine separation, the potatoes were again washed to remove the salt. They were bagged, identified by lot, farm, and area, and placed in bins until packaged for distribution.

In order to provide the consumer panel with samples representative of the crop, potatoes from all the farms in a given area were composited by specific gravity class. Each consumer sample contained potatoes from all farms representing that specific gravity class in a given growing area.

Samples for the consumer were packed with shredded paper in corrugated boxes 9 x 9 x 7½ inches All the boxes were packed and sealed at the same time. The second samples were held in a cooler at 40° F. for two weeks before being mailed. All the potatoes had been stored in farm cellars at a temperature of approximately 40° F. The first samples were mailed to the consumer panel the first week in January.

Selection of Consumer Panel: On the basis of population concentration, Oregon may be divided into three approximately equal groups: the Portland area, the Willamette Valley south of Portland, and the remainder of Oregon. A panel of 139 homemakers was drawn by sampling systematically from city directories. The distribution of the households represented on the panel was in keeping with population concentration.. The families ranged in size from 2 to 9 persons, with the majority having 2 to 5 members.

Information Requested from the Consumer Panel: Questions were asked to elicit responses concerning preparation methods as well as homemakers' reactions to qualities of high and low specific gravity potatoes. The check-sheet included in each box of potatoes listed questions about the sample when baked, mashed and boiled. Questions concerning each method of preparation included details, such as temperature and time for baking, and the amount of water used for boiling. In addition, each respondent was asked to select from a diagram supplied with the questionnaire the size of potato that she preferred for baking, mashing, boiling, and frying. She was also asked to state the frequency with which she customarily serves potatoes prepared by each of these methods and in casseroles.

For homemakers' evaluation of potatoes of different specific gravity, the questions fell into the following groups: (a) overall rating of each sample for each of three methods of cooking; (b) rating of special characteristics applicable to baked, mashed and boiled potatoes; (c) characteristics especially liked or disliked about each sample when prepared by the homemaker's usual cooking methods; (d) the suitability of each sample for all-purpose home use.

Laboratory Study: A laboratory study was carried out which paralleled the consumer study. This was planned to permit comparisons of judges' evaluation of certain characteristics with consumer responses concerning

the same characteristics. Each quality deemed of importance for consumer acceptance was studied in the laboratory. For example, for baked potatoes, the characteristics of mealiness, flavor, skin tenderness and color of flesh were evaluated by the consumer panel and were also given numerical scores by the laboratory judging panel. The appearance of sloughing during cooking was recorded for boiled and mashed potatoes; in addition, smoothness of mashed potatoes was judged.

An analytical panel, composed of four trained judges, scored the potatoes prepared by baking, boiling and mashing. Numerical ratings were given from 1 (poorest or least) to 5 (best or most) for the characteristic under consideration. Four replications were carried out.

Ten pounds of potatoes of varying specific gravities from each farm in each area were reserved for laboratory testing. The appearance of these potatoes was recorded on check sheets for reference when examining the comments of the consumer panel. Potatoes from each farm were kept separate, rather than composited as was done for the consumer panel. In the analysis of variance this provided an estimate of error caused by location from which potatoes were drawn.

Three methods of preparation were used. *Baking.*—Eight-ounce potatoes were selected. They were scrubbed, placed on wire racks, and baked at 400° F. for about 1½ hours, to an internal temperature of 218° F. *Boiling.*—Potatoes for boiling were selected to weigh close to eight ounces. They were washed, pared, cut into quarters, placed in boiling water to cover, and boiled gently until judged tender and done when pierced with the tip of a paring knife. *Mashing.*—Larger potatoes were selected for mashing, weighing close to 12 ounces. After being prepared and cooked as described for boiled potatoes, they were drained and whipped at the medium speed of an electric mixer. The potatoes were served and judged while hot.

Analysis of Data: For purposes of analysis, consumers' responses to each question were given numerical values of 3 for "most or best" to 1 for "least or poorest" of a given characteristic. As previously mentioned, the laboratory panel assigned scores of 5 to 1 for the same characteristics. The analysis of variance was used to determine differences due to the area where grown, and also to the specific gravity. For the consumer panel, the error term was derived from home to home variation. For the laboratory panel, the error term was farm to farm variation.

Results

Consumer Panel

Frequency of Use of Potatoes: Potatoes were served an average of 6.4 times weekly. Answers to the question, "About how often do you prepare potatoes by baking, boiling, mashing, frying, and in casseroles?", showed that boiled potatoes were served more often than those prepared by any other cooking method. Frequency of use of each preparation method was: boiled, 29.6 per cent; mashed, 25.7; baked, 22.4; fried, 14.6; and for casseroles, 7.7 per cent. Percentages are on the basis of total number of times weekly that potatoes were used. For example out of 866 times weekly that potatoes were served by the homemakers on this panel, 256 times, or 29.6 per cent, they were served as boiled potatoes.

Every respondent used two or more methods weekly for preparing potatoes, with the majority using three methods. At least once a week, 84 per cent of the homemakers prepared potatoes by baking, 85 prepared potatoes by mashing, 78 boiled potatoes, 41 fried potatoes and 26 per cent used potatoes in casseroles.

Preference for Size of Potato for Different Cooking Methods: The distribution of preferences for the different size potatoes illustrated in the questionnaire are expressed in percentages in table 1. In general, the larger sizes were preferred for baking, mashing and frying. For boiling, preference was indicated for both small and large sizes. The small sizes were probably boiled whole, whereas the large sizes were prepared by paring and cutting. For baking, the 8-ounce size was preferred by nearly half of the homemakers, and the largest size shown, 12 ounces, by nearly one fourth of the homemakers. Nearly three fourths of the homemakers expressed a preference for 8 or 12 ounce potatoes for mashing. Approximately two thirds of the homemakers liked these same large sizes for frying.

TABLE 1.—*Sizes of potatoes preferred by consumer panel for four methods of cooking given as per cent of responses.*

Method of Cooking	Weights of Potatoes — Ounces				
	4	5	6	8	12
	Per cent	Per cent	Per cent	Per cent	Per cent
Bake	2.2	7.4	17.8	49.6	23.0
Boil	25.4	20.0	8.5	25.4	20.8
Mash	7.1	10.3	8.7	39.7	34.1
Fry	11.0	11.9	12.7	29.7	34.8

Preparation and Cooking Methods: *Baking.*—About two thirds of the homemakers greased the skins of potatoes prior to baking, whereas only about one out of seven wrapped potatoes in foil. The majority, 82.7 per cent, baked potatoes at temperatures of 350 to 400° F. Only a few reported using temperatures as low as 300° F. or as high as 450° F. One person baked at 250° F. and one at 475° F. Baking time varied according to size of potatoes and temperature used. About one half the homemakers reported baking the potatoes for one hour and about one fourth said they baked potatoes for 45 minutes.

Mashing.—All but four respondents peeled and cut up potatoes for cooking prior to mashing. About one half the homemakers covered them with water, whereas the others used only enough water to steam or partly cover the tubers. Slightly more than one half of the mashed potatoes served were whipped with an electric mixer, the others were mashed with hand mashers.

Boiling.—Three fourths of homemakers who boiled potatoes, peeled and cut them up before cooking. About one half of the respondents said they covered the cut potatoes with water for cooking.

Consumer Response to High and Low Specific Gravity Potatoes: Each of the 139 respondents prepared samples of experimental potatoes by baking, mashing and boiling, and answered questions pertaining to cooking

performance and eating quality. By means of the analysis of variance of consumers' responses highly significant differences caused by specific gravity were found for the characteristics of mealiness and sloughing.

Potatoes in the two specific gravity classes did not have noticeable differences in flavor, color, smoothness of mashed potatoes nor skin tenderness of baked potatoes. Possible differences due to growing area were not detected by the panel.

The homemakers' ratings for mealiness and for sloughing of the two specific gravity classes are summarized in table 2. These responses were consistent for all three growing areas represented by the potato samples. Many favorable comments were made regarding how well potatoes of low specific gravity held their shape when boiled.

Effect of Mealiness and Sloughing on Overall Desirability of Potatoes: Homemakers' opinions of high specific gravity potatoes and of low specific gravity potatoes for all-purpose use are given as percentages in table 3. In general, homemakers considered the high specific gravity potatoes somewhat more satisfactory for all-purpose use than the low specific gravity ones.

TABLE 2.—*Consumer ratings for degree of mealiness and sloughing of gravity-graded potatoes, given as per cent of responses for each characteristic.*

Potato Sample	Mealiness (Dry, Crumbly Texture)			Sloughing		
	Very Mealy	Somewhat Mealy	Not Mealy	Retained Normal Shape	Broke Apart Slightly	Broke Apart Very Much
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
High Specific Gravity	40.1	42.6	17.2	56.1	37.5	6.3
Low Specific Gravity	24.6	39.7	35.5	87.0	11.1	1.8

TABLE 3.—*Hmemakers' opinions of gravity-graded Russet Burbank potatoes for all-purpose use, given as per cent of responses.*

Potato Sample	Very Satisfactory	About Average	Not Satisfactory
	Per cent	Per cent	Per cent
High Specific Gravity	52.6	43.6	3.8
Low Specific Gravity	51.8	39.3	8.9

Some of the factors that influenced the opinions of homemakers in judging the desirability of potatoes for all-purpose use were: physical characteristics of the tubers such as shape, size, skin netting, smoothness and flaws as well as flavor, texture, and cooking performance.

In deciding suitability for all-purpose use one factor often counterbalanced another. If a homemaker found a sample of potatoes satisfactory for her favorite cooking methods, although unsatisfactory for a seldom-used cookery method, she rated it high as an all-purpose potato.

Apparently the homemaker was willing to overlook a less desirable characteristic for another very good characteristic. Though sloughing of boiled potatoes was undersirable, moderate sloughing was not considered important if other characteristics were satisfactory. For example, one respondent who reported that a sample went to pieces when boiled remarked, "This was such a good-tasting potato one can almost overlook its fault."

Ratings for all-purpose use naturally reflect individual preferences. Although most comments indicated that homemakers liked mealy baked potatoes, a few objected to them because of that characteristic. A few respondents commented that they liked the moistness of a baked potato they judged as not mealy.

Eighty per cent of the homemakers who said that baked potatoes were very mealy also said that they liked them very much for baking. The other twenty per cent liked the very mealy potatoes fairly well. None said that they did not like the very mealy potatoes for baking.

When baked potatoes were judged somewhat mealy or not mealy, approximately forty per cent of the homemakers reported liking them very much, about forty per cent liked them fairly well, and fifteen per cent said they did not like them when prepared by this method.

When potatoes to be served as "boiled" potatoes broke apart a great deal during cooking, homemakers generally considered them undesirable for this method of preparation. However, if the potatoes were boiled for the purpose of mashing, most homemakers reported that they liked them fairly well and several reported that they liked the potatoes very much for mashing. One of the latter made the comment, "Although these broke apart more in cooking, this didn't seem to inconvenience the one mashing the potatoes."

Laboratory Panel

Highly significant differences caused by specific gravity were found by the laboratory panel for sloughing and for mealiness. High specific gravity potatoes were more mealy when cooked by each method than were low specific gravity potatoes. Sloughing was more extreme for high specific gravity potatoes. In addition to these findings, highly significant differences were found for flavor and skin tenderness of baked potatoes. Flavor was better in the case of high specific gravity baked potatoes, whereas the skin was more tender for those of low specific gravity.

Summary and Conclusions

Oregon-grown Russet Burbank late-crop potatoes of high specific gravity and of low specific gravity were judged for cooking qualities and palatability by a consumer panel of 139 homemakers and by a trained laboratory panel. Information was also obtained from the homemakers regarding their cooking techniques, preferences for size of potato for

various cooking uses, and the frequency with which potatoes are prepared by different methods.

For both the consumer and laboratory panels, specific gravity was found to have a highly significant effect on mealiness and sloughing scores. Potatoes of high specifific gravity were more mealy. Potatoes of low specific gravity sloughed less when boiled. The laboratory panel found the flavor better in baked potatoes of high specific gravity, and the skins more tender in baked potatoes of low specific gravity. No differences were found due to growing area.

Both panels reported preferring very mealy potatoes for baking, and potatoes that did not slough for serving as boiled potatoes. For potatoes to be mashed, however, neither panel considered moderate sloughing as objectionable. Homemakers judged potatoes of high specific gravity somewhat more satisfactory for all-purpose use than those of low specific gravity, although when used for special purposes such as boiling, low specific gravity potatoes were preferred.

The consumer panel reported preparing potatoes most frequently by boiling, next by mashing, followed by baking. Frying is done somewhat less often, and casseroles are prepared rather infrequently.

For preparation methods, the consumer panel reported that when potatoes are to be served boiled or mashed, they frequently are pared, cut up and covered with water for cooking. Potatoes for baking are usually greased, then baked for one hour at oven temperatures of 350 to 400° F.

For potato sizes, the homemakers reported preferring potatoes of eight to twelve ounces for baking, mashing and frying. For boiling, both small and large sizes were considered satisfactory.

The similarity of response of the consumer panel and the laboratory panel was notable. For the two qualities of mealiness and sloughing, both panels found differences due to specific gravity, but no differences due to growing area.

Both specific gravity groups were judged by the homemakers to be mealy, the low specific gravity potatoes being fairly mealy and the high specific gravity ones very mealy. According to Hotchkiss (3) the characteristic of mealiness is desired by consumers regardless of the way in which potatoes are served.

Russet Burbank potatoes of high specific gravity were judged excellent for baking and were preferred for mashing. Because of their pronounced tendency to slough they were considered less satisfactory for boiling. Russet Burbank potatoes of low specific gravity, although possessing a fair degree of mealiness, showed less tendency to break apart in cooking. They were, therefore, considered superior for boiling. For other preparation methods, such as casseroles, stews and salads, in which retention of shape is important, low specific gravity Russet Burbank potatoes would be most suitable.

Literature Cited

1. Cravens, M. E. 1947. Housewives' reactions to Michigan potatoes. Mich. Exp. Sta. Quar. Buli. 30: 125-130.
2. Heinze, P. H., Mary E. Kirkpatrick, and Elsie F. Dochterman. 1955. Cooking quality and compositional factors of potatoes of different varieties from several commercial locations. U. S. Dept. of Agr. Tech. Bull. No. 1106.

3. Hotchkiss, Alida S. 1941. Consumer buying of potatoes and store offerings. Cornell Univ. Agr. Exp. Sta. Bull. 764.
4. Mackey, Andrea, Joy Stockman and Ida Cecil. 1958. Availability of fresh fruits and vegetables in representative retail markets in Oreg. Agr. Exp. Sta., Prog. Rep.
5. ————, Ida Cecil, Sue Joiner and Joy Stockman. 1958. Survey of specific gravity of Russet potatoes grown in Central Oregon and the Klamath Basin, 1957 crop. Amer. Potato Jour. 35: 739-742.
6. Nylund, R. E. and A. J. Poivan. 1953. The influence of variety and date of planting on the relative cooking quality of potatoes graded according to specific gravity. Amer. Potato Jour. 30: 107-118.
7. Phillips, C. D. 1951. Buying practices of Louisville consumers for sweet potatoes, swweet corn, and potatoes. Ken. Agr. Exp. Sta. Bull. 574.
8. Smith, Ora. 1951. Potato quality. Amer. Potato Jour. 28: 732-737.
9. Stevenson, F. J. 1948. Potato preferences among household consumers. U. S. Dept. Agr. Misc. Pub. No. 667.

"The ORTHO program this year helped me increase my yields by an average of 20 bags (potatoes) per acre,"

states Mr. Guy Lockerman, owner and manager, Sunset View Farms, Middletown, Delaware.

ORTHO offers a crop protection program tailor-made for your area. Your ORTHO Fieldman knows the particular problems of your area. When you buy the ORTHO program you get the benefit of this technical field service, a half century of research, and all the scientific know-how that have made ORTHO America's number one line of agricultural chemicals.

CALIFORNIA SPRAY-CHEMICAL CORP. ORTHO
A SUBSIDIARY OF CALIFORNIA CHEMICAL COMPANY
Richmond, California
Offices throughout U. S. A. *"Helping the World Grow Better"*
TM'S ORTHO, ORTHOCIDE REG. U. S. PAT. OFF.

PSEUDOMONAS FLUORESCENS IN RELATION TO CERTAIN DISEASES OF POTATO TUBERS IN MAINE[1]

DONALD FOLSOM[2] AND B. A. FRIEDMAN[3]

In recent years the red-xylem disease, pink eye and bruise infection of the potato (*Solanum tuberosum* L.) have been studied in Maine. These diseases were thought at first to be distinct but have been found to have a common characteristic in the prevalence of *Pseudomonas fluorescens* Migula in affected tissues.

The red-xylem disease (12) in stored Maine-grown potatoes is most common in the larger tubers of the Katahdin variety. It is characterized by a lesion at the stolen scar (Figure 1), a cavity extending from the stolon scar into the center of the tuber (Figure 2), black parenchyma lining the cavity, and reddish-brown xylem (Figures 2-4). Its importance seems to be limited to being an occasional nuisance to potato growers and inspectors.

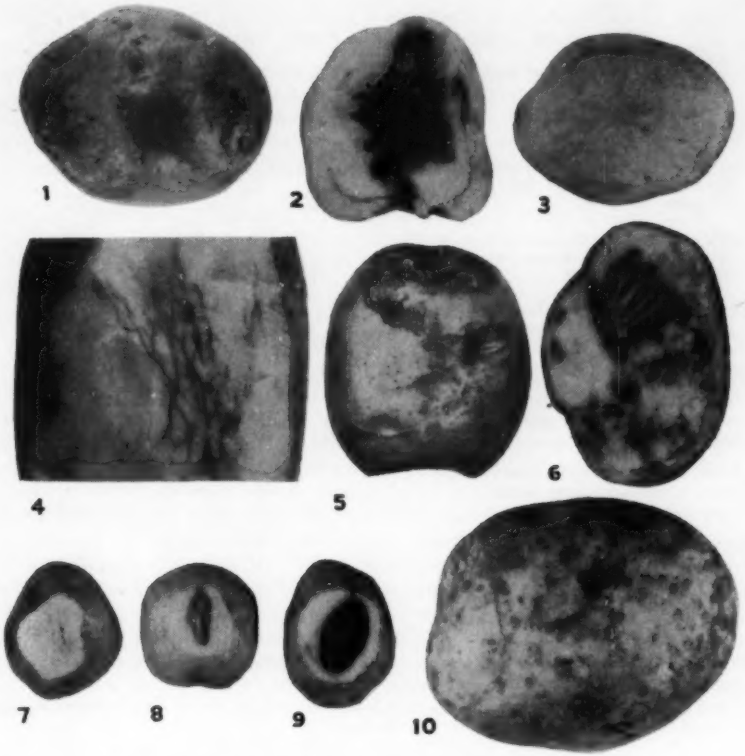
The pink-eye disease (13, 14) in Maine is particularly confined to tubers grown in fields containing wilt caused by *Verticillium albo-atrum* Reinke & Berth. It appears during the latter part of the growing season and usually leads uninitiated potato growers to think that late blight is present in its initial stage of tuber rot. In a wilt-affected field, pink eye often is abundant where soil-moisture content is high and absent where the soil is very dry. It is characterized by pink eyes, internal cavities, and reddish-brown to black internal discoloration (Figures 5-6). The externally evident pink discoloration is in the parenchyma; it shows through the skin, and may extend between the eyes as pink blotches. In storage, the affected parenchyma may first dry out and turn light brown, then finally may become wrinkled, sunken, and cracked. With discolored xylem and black lining of cavities, pink eye overlaps the red-xylem disease with respect to symptoms.

Bruise cracks in potato tubers may escape infection (Figure 7) or may be the point of entrance of micro-organisms that cause discoloration and decay of the parenchyma (Figures 8-9). Bruise infection has become more important than formerly in Maine on account of the commercial washing of potatoes (11), which makes bruise infection more obvious. Washing may also be followed soon by reddish-brown spotting of the parenchyma at the lenticels (Figure 10).

ISOLATION AND IDENTIFICATION

In the course of a decade, 1018 transplants were made from discolored xylem and parenchyma in tubers from various sources (Table 1). From 48 to 72 per cent of the transplants contained *P. fluorescens* when the source of transplant was (1), dark parenchyma of stolon-scar lesions in red-xylem tubers; (2) dark parenchyma lining cavities in red-xylem and pink-eye tubers; (3) reddish-brown parenchyma in unbruised pink-eye

[1]Accepted for publication August 11, 1958.
[2]Formerly Plant Pathologist, Maine Agricultural Experiment Station, Orono, Maine.
[3]Senior Plant Pathologist, Market Pathology Laboratory, Agricultural Marketing Service, United States Department of Agriculture, New York, N. Y.



FIGURES 1-10.—Natural sources of *Pseudomonas fluorescens*.

FIGURE 1.—Lesion at stolon scar of tuber with red-xylem disease. FIGURE 2.—Discolored xylem and black lining of cavity in longisection of tuber of Figure 1. FIGURE 3.—Discolored xylem in transection of tuber. FIGURE 5.—Pink flesh showing through skin at distal end of "pink-eye" tuber from plant with Verticillium wilt. FIGURE 6.—Discolored xylem, blotches, and dark lining of cavity in longisecton of pink-eye tuber from plant with Verticillium wilt. FIGURES 7-9.—Tubers with, respectively, noninfected bruise cracks, redish-brown fiesh bordering bruise crack, and black flesh at site of bruise cracks. FIGURE 10.—Reddish-brown lesions at lenticels, following commercial washing.

and recently washed tubers; (4) reddish-brown parenchyma adjoining bruise cracks; or (5) brown to black parenchyma adjoining bruise cracks. The percentage of transplants that contained *P. fluorescens* was somewhat lower when transplants were made from discolored xylem in red-xylem and pink-eye tubers, because *V. albo-atrum* alone was present in some xylem transplants from pink-eye tubers, or when they were made from brown to black parenchyma of lesions not obviously adjoining bruise cracks, because such lesions sometimes yielded only *Fusarium coeruleum* (Lib.) Sacc., *F. sambucinum* Fckl. f. 6 Wr., or *Phoma tuberosa* Melhus,

TABLE 1.—*Frequency of Pseudomonas fluorescens in 1018 tissue transplants from certain defects in potato tubers 1947-1957.*

Defects	No. of Sample Lots	Transplants	
		Total Number	Percentage Yielding *P. fluorescens*
Dark parenchyma of stolon-scar lesion in red-xylem tuber (Figure 1)	11	32	72
Dark parenchyma lining cavities in red-xylem and pink-eye tubers (Figures 2 and 6)	14	44	66
Discolored xylem in red-xylem and pink-eye tubers (Figures 2-4 and 6)	47	207	41[1]
Reddish-brown parenchyma in unbruised pink-eye and recently washed potatoes (Figures 5, 6, and 10)	54	314	57
Brown to black parenchyma in red-xylem, pink-eye, and other unbruised tubers	38	285	32[2]
Reddish-brown parenchyma adjoining bruise cracks (Figure 8)	5	71	51
Brown to black parenchyma adjoining bruise cracks (Figure 9)	7	65	48

[1]Some transplants from discolored xylem in pink-eye tubers contained only *Verticillium albo-atrum.*

[2]Some of the "other" tubers yielded only *Fusarium coeruleum, F. sambucinum* f. 6, or *Phoma tuberosa* from discolored parenchyma.

Rosenbaum & Schultz. The frequency with which *P. fluorescens* was found in certain tuber defects strongly suggested the possibility of a causal relationship.

In cases where bacterial outgrowth occurred from a transplant from discolored xylem or parenchyma, the presence of *P. fluorescens* was detected by inoculation of potato slices with cultures of the bacteria and examination for the characteristic symptoms described below. In several dozen instances these bacterial cultures were studied in detail. They were purified from single colonies streaked on 6 successive nutrient-agar plates. The morphological, cultural, and physiological characteristics of the pure cultures were determined by standard techniques (21). Sugars were made up in synthetic broth, sterilized by Seitz filtration, and added aseptically to the basal medium; organic acids were heat sterilized. Forty similar strains, which comprised the great majority of the studied isolated strains, were characterized as follows: Short, gram-negative rods, motile with 1 to 5 polar flagella, without spores or capsules; nutrient-agar colonies white, translucent, or creamy, circular, slightly raised, smooth, with margins regular to minutely lobed; yellow-green fluorescence in agar and asparagine broth, with no pyocyanin formed; gelatin liquefied; nitrate

reduction to nitrites positive but slight; indol and hydrogen sulphide not formed; acid but no gas from dextrose, sucrose, and glycerol, and weak acid formation or none in lactose or maltose broths; alkaline reaction in acetic acid, citric acid, lactic acid, or succinic acid media; growth absent or weak and no alkali formed in sodium tartrate broth. From descriptions of the species of *Pseudomonas* and laboratory comparison with 15 named species, including several which have been reported to infect potatoes under natural or artificial conditions as *P. marginalis* (Brown) Stevens (3 strains), *P. fluorescens* (6 strains), *P. cichorii* (Swingle) Stapp, *P. atrofaciens* (McColloch) Stevens, *P. tabaci* (Wolf and Foster) Stevens, and *P. syringae* van Hall (4 strains), the 40 potato isolates appeared to belong to a single species grouping that fitted most closely *P. fluorescens* (4, 7, 9, 19,22,23).

Inoculation of Potato Slices

Of the 40 strains identified as described above, 36 were used during the period 1953-1956 to inoculate 189 potato slices by keeping the slices covered for several hours with a broth culture. By the next day there was an accumulation of liquid on the slice, a discoloration (cream to yellow, olive, or brown, but mostly yellow or yellowish), fluoresence of the wet discolored surface under ultraviolet light (Figures 15 and 16), and usually a softening of the slice. The effects of any one isolate were not influenced by the use of slices of different potato varieties or by the taking of slices from different parts of the tuber. Such effects of inoculating potato slices made it possible, as indicated above, to make a quick macroscopic test of the presence of *P. fluorescens* in discolored xylem or parenchyma. Using some of our cultures, Bonde (3) has shown that seed-piece decay by *P. fluorescens* may be as severe as that caused by *Erwinia atroseptica* (van Hall) Jennison and that the two organisms react differently to certain antibiotics.

Inoculation of Potato Tubers

Stab inoculations of stolons near the tubers in greenhouse-grown plants were followed by red-xylem symptoms, and *P. fluorescens* was recovered from discolored tissues. Inoculation of the surface of immature tubers in the greenhouse (with broth-soaked cotton) resulted in stolon-scar lesions and xylem discoloration when inoculation was at the stem end whereas pink eye resulted when inoculation was at the eye end; the organism was recovered. A day's immersion in broth culture, followed by a month's storage, had no effect on year-old tubers. In freshly dug tubers, however, this treatment produced reddish-brown discoloration by the stolon scar and in the xylem and produced some deep soft rot; transplants yielded *P. fluorescens*.

In another series of inoculations, a depression was gouged out in the stem-end half of each tuber and filled with a broth culture. The tuber half was kept in a high-humidity atmosphere (on a screen over water in a desiccator) with the depression up, and sterile water was added as needed to keep water in the depression. After two days the half-tubers were stored for a month at 42° F. Thirty per cent then had a dark green, greenish-brown, or greenish-black rot and reddish-brown xylem (Figure

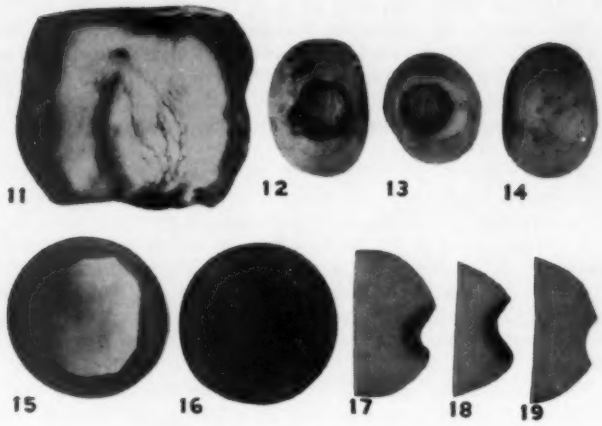
11); 60 per cent had a shallow, light brown rot, and a third of these also had reddish-brown xylem. All defects yielded *P. fluorescens*.

The 40 strains of *P. fluorescens* identified by standard techniques were used in the internal inoculation of tubers. Each tuber end was broken open with a large scalpel, and agar bearing the bacteria was placed on the untouched flesh thus exposed. The lifted-up portion of the tuber was replaced and held in position with a rubber band. The tuber was wrapped in waxed paper and placed in 35° F. storage. Three weeks later, some tuber ends had a dark lesion coated with fluorescent green slime (Figures 12 and 17). The internal inoculation was repeated later in other tubers, with similar results. Strains that produced rot in the first series also produced rot in the second series, and rot was limited to these strains. In both series the rot was produced only by strains that had consistently, or usually, softened potato slices. No rot was produced by non-softening strains or by certain softening strains. The rot-producing strains had been obtained from discolored xylem, pink parenchyma, or dark parenchyma lining a cavity, in the years 1947, 1949, 1950, 1951, or 1952, so that source or age of the strain did not determine the capacity to produce the rot. Attempts to reisolate *P. fluorescens* from the dark parenchyma of the lesion at the junction with healthy flesh either yielded the organism (Figures 13 and 18) or yielded nothing, the latter indicating that discoloration can precede invasion by the bacteria. After further storage for several weeks, some lesions had continued their advance whereas others had been corked off and had dried out. Further transplants again yielded either the organism or nothing.

Bruise-Crack Infection

The internal inoculations just described would differ from the inoculation of fresh bruise cracks, natural or artificial, because contaminating organisms in or on the skin would have access to the water-filled fresh bruise cracks in the latter. Washed tubers from cold storage were bruised so that cracks extended to the center of the tuber. Some tubers were then immersed momentarily in a diluted broth culture, and all were washed again and placed in 35° F. storage. In a month, dark progressive rot like that produced by the internal tuber inoculations had developed in the deep portions of bruise cracks, and transplants from 82 per cent of the lesions yielded *P. fluorescens*. The rot was about half as frequent in the control tubers as in the broth-inoculated tubers, presumably because of natural infection by the organism as a skin inhabitant.

In a second series of bruised tubers, none was inoculated artificially but some were disinfected before being washed, bruised, and stored. In the non-disinfected tubers 78 per cent of the bruises developed lesions. The number of bruises that developed lesions was reduced 23, 42, and 29 per cent by 10-minute dips in dilute solutions containing 100 ppm Agrimycin, 0.1 per cent sodium hypochlorite and 0.06 per cent Phygon (2,3—dichloro—1,4—naphthoquinone), respectively. Most of the lesions were thin and reddish-brown (Figure 8) and predominantly yielded *P. fluorescens*. Some were dark (Figure 9), in some instances with a fluorescent slimy green coating on dark flesh lining a cavity; *P. fluorescens* was obtained from transplants. This last type of severe rot occurred at 35° F. but not at 50° or 70°.



FIGURES 11-19.—Results of inoculation with *Pseudomonas fluorescens*.

FIGURE 11.—Discolored xylem in tangential section of tuber inoculated at proximal end. FIGURE 12.—Black flesh, coated with fluorescent green slime, resulting from inoculation of flesh under broken-out segment of tuber. FIGURE 13.—Black flesh, coated with fluorescent green slime, resulting from inoculation with reisolate from lesion of Figure 12. FIGURE 14.—Control to Figures 12 and 13. FIGURE 15.—Tuber slice, a day after inoculation, showing fluorescence under ultraviolet light. FIGURE 16.—Control to Figure 15, after aplication of sterile water. FIGURES 17-19.—As for Figures 12-14, respectively, in longisection.

OTHER TESTS WITH POTATOES

The use of red-xylem tubers as seed had no apparent effect on the plants or crop. Soil in which red-xylem tubers had been produced was used for growing potatoes a second season, but no red-xylem tubers were found in the second crop.

INOCULATION OF OTHER VEGETABLES

Slices of carrot roots, onion bulbs, and cucumber fruit, leaves of head lettuce, escarole and witloof chicory, and pods of string beans, green peas and fava beans were inoculated by needle with 48- to 72-hour-old cultures of 28 strains of *P. fluorescens*. Each vegetable was inoculated at least 4 times. All results were quite variable. Most of the strains caused small, dark, firm rots on leaves of lettuce, escarole and witloof chicory. About one-half of the strains caused small, dark necrotic spots on pods of string beans and fava beans, and about one-third caused similar spots on green pea pods. Except for an occasional slight reaction, nearly all the strains failed to infect carrot, cucumber, or onion slices.

DISCUSSION

P. fluorescens is generally considered to be a harmless soil organism (4, p. 90; 5; 7, p. 82; 9, p. 292) but has been isolated previously from

potato (1; 8; 9, p. 292; 16; 17; 24). A rot and vascular browning of potato tubers caused by bacteria resembling *P. fluorescens* has been reported (15, 18). *P. axanthochlora* (Schuster) Stapp was reported to be phytopathogenic form of the saprophytic *P. fluorescens* (20) and to infect potatoes under natural conditions (10, 20). *Bacillus caulivorus* Prillieux and Delacroix, reported to infect potatoes, was considered to be synonymous with *P. fluorescens* (9, p. 275).

The results obtained in the present work indicate that *P. fluorescens* is no more than a weak parasite, under most conditions, on potatoes and certain other vegetables. Others have reported *P. fluorescens* to be a weak parasite of lettuce injured by frost (25), to infect celery weakened by low temperature in storage (2), and to cause slight infection on mature pear fruit but to be unable to infect growing parts of 16 species of plants (6). Under certain conditions, however, the organism is an active parasite of potato and even when not very active, as in some bruise rot, can be important.

The variable results of carbohydrate fermentation reactions by the different isolates of *P. fluorescens* observed during the present work confirm similar variations reported previously (19).

Summary

Fluorescent bacteria were isolated frequently from discolored xylem and parenchyma of Maine-grown potato tubers that had the red-xylem disease, pink eye, or infected bruise cracks. Isolates were identified as strains of *Pseudomonas fluorescens*. Some strains produced softening of potato slices and a progressive black rot inside tubers, whereas other strains produced neither; the former did not lose their pathogenicity in the course of several years' maintenance in broth. In the field, pink eye, associated with Verticillium wilt, was correlated positively with soil moisture. Black rot was more active at 35° F. than at 50° or 70°. Infection in bruise cracks was less frequent in tubers dipped in solutions of Agri-mycin, sodium hypochlorite or Phygon previous to bruising than in comparable untreated, noninoculated tubers. Stolon and tuber stem-end inoculation induced red-xylem symptoms. Tuber eye-end inoculation induced pink-eye.

Literature Cited

1. Ark, P. A. 1946. Some laboratory and field data on ring-rot of potatoes in California. Amer. Potato Jour. 23: 170-181.
2. Barlow, B. 1904. A rot of celery. Ontario Agr. College Bull. 136: 19-20.
3. Bonde, R. 1953. Preliminary studies on the control of bacterial decay of the potato with antibiotics. Amer. Potato Jour. 30: 143-147.
4. Breed, R. S., E. G. D. Murray, and A. P. Hitchens. 1948. Bergey's Manual of Determinative Bacteriology. 6th Ed. 1529 Pp. Williams and Wilkins, Baltimore, Md.
5. Burkholder, W. H. 1939. The taxonomy and nomenclature of the phytopathogenic bacteria. Phytopath. 29: 128-136.
6. Clara, F. M. 1934. A comparative study of the green-fluorescent bacterial plant pathogens. New York (Cornell) Agr. Exp. Sta. Mem. 159. 36 Pp.
7. Dowson, W. J. 1949. Manual of Bacterial Plant Diseases. 183 Pp. A. & C. Black, London.
8. ————, and D. Rudd Jones. 1951. Bacterial wet rot of potato tubers following *Phytophthora infestans*. Ann. Appl. Biol. 38: 231-236.

9. Elliott, Charlotte. 1930. Manual of Bacterial Plant Pathogens. 349 Pp. William and Wilkins, Baltimore, Md.
10. Foex, E., and M. Lansade. 1936. Action pathogene d'une bactérie isolée de tubercules de Pomme de terre. Compt. Rend. 202: 1939-1941.
11. Folsom, D. 1955. Washing potato salvage stocks. Maine Farm Res. 31: 24-26.
12. ————, J. S. Getchell, and R. Bonde. 1948. Bacterial red xylem disease of potato tubers in Maine. Pl. Dis. Reptr. 32: 230-231.
13. ————, O. Wyman, and E. Westin. 1951. Potato Verticillium wilt. Maine Agr. Ext. Circ.265.
14. Friedman, B. A., and D. Folsom. 1953. Storage behavior of Kennebec potatoes infected by *Verticillium albo-atrum*. (Abst.) Phytopath. 43: 108.
15. Garrard, E. H. 1945. A storage rot of potatoes caused by a fluorescent organism resembling *Pseudomonas fluorescens* (Flügge) Migula. Canad. Jour. Res., Sec. C 23: 79-84.
16. Harrison, F. C. 1906-1907. A bacterial rot of the potato, caused by *Bacillus solanisaprus*. Centr. Bakter., Parasitenk. Abt. 2. 17: 34-39, 120-128, 166-174, 384-395.
17. Israilski, V. P., and E. V. Runow. 1925. Resistance of potato varieties to bacterial diseases, and virulence of bacteria. Morbi Plantarum, Leningrad 14: 1-6. Abst. in Rev. Appl. Mycol. 5: 574, 1926.
18. Lacey, Margaret S. 1932. Studies in bacteriosis. XIX. Part 2, Ann. Appl. Biol. 19: 190-203.
19. Munoz, J., M. Scherago, and R. H. Weaver. 1949. A serological study of members of the *Pseudomonas* genus. Jour. Bacteriol. 57: 269-278.
20. Schuster, J. 1912. Zur Kenntnis der Bakterienfaule der Kartoffel. Arb. Kaiserl. Biol. Anstalt Land- u. Forstwirtsch. 8: 452-492.
21. Soc. Amer. Bact., Comm. Bact. Technic. 1955. Manual of methods for pure culture study of bacteria. Lflt. II, 24 Pp.; IV, 24 Pp.; V, 28 Pp. Biotech. Pub., Geneva, N. Y.
22. Stanier, R. Y. 1947. Acetic acid production from ethanol by fluorescent pseudomonads. Jour. Bacteriol. 54: 191-194.
23. ————, O. Hayaishi, and M. Tsuchida. 1951. The bacterial oxidation of tryptophan. I. A general survey of the pathways. Jour. Bacteriol. 62: 355-366.
24. Starygina, L. P., and U. G. Oksent'ian. 1956. (Characteristics of the smooth (S) and rough (R) forms of *Ps. fluorescens liquefaciens*). Mikrobiologiia 25: 529-432. Quoted in U.S.D.A. Bibliog. Agr. 21(4): 18, 1957.
25. Verona, O., and P. Pasinetti. 1936. (On a wilt of *Lactuca sativa* L.) Bol. Inst. Agr., Pisa 11: 364-375. Abst. in Rev. Appl. Mycol. 16: 297, 1937.

A YELLOW STRAIN OF POTATO VIRUS X[1]

A. J. HANSEN[2] AND R. H. LARSON[3]

One of the characteristics by which strains or types of potato virus X can be classified into groups is the symptom expression on certain host plants. In the present studies, *Nicotiana rustica* L. was found to be especially suitable for this purpose, since this host distinguishes between the mottle, the ringspot, and the brownspot type (11, 12, 16, 17) more clearly than other plants. During an investigation of naturally occurring and induced mutants in potato virus X, a fourth symptom type of this virus was discovered, which seems to warrant the establishment of an additional group because of its distinctive characteristics.

Expressed sap from a potato plant of the variety Green Mountain, carrying the previously reported strain X 8 (13, 26, 27), was diluted and inoculated to *Gomphrena globosa* L., a local lesion host of potato virus X. Twenty-five local lesions incited by this strain were removed with a 0.5 cm. cork borer, diluted with 2 cc of water each and separately inoculated to leaves of *N. rustica*. These plants were held at 18-20° C. under 16 hours daylight.

Most of the inoculated leaves of *N. rustica* developed mottle and ring symptoms typical of those incited by strain X 8. However, the transfers from 2 lesions that appeared on *G. globosa* 72 hours later and remained smaller than those typical of X 8 incited lesions, incited olive-yellow chlorotic lesions ½ inch in diameter after 10 days on *N. rustica*. These lesions were readily distinguished from those of the green mottle type. During the next 10 days, the color of bright yellow lesions increased in intensity. The lesions extended somewhat along the veins, but no necrotic symptoms were observed (Figure 1). Each of 8 of the yellow lesions were sub-transferred to *N. rustica*, where they incited uniformly bright, yellow lesions. Leaves of these *N. rustica* plants were dried over $CaCl_2$ and used as a stock source of the new strain throughout the investigation.

In order to test the uniformity of the yellow strain, the stock material was diluted 1:10,000 and inoculated to *G. globosa*. Forty-five of the lesions were separately transferred to *N. rustica*, where they induced a total of 3434 yellow lesions. Since no other symptoms appeared on the inoculated leaves, it was concluded that the strain was pure in respect to symptom expression. The lesions on *G. globosa* in this test, as well as those in other transfers, appeared 24-48 hours later and reached only ⅔ of the size of those caused by other strains of potato virus X (Figure 2). The lesions incited on *G. globosa* by the yellow strain were consistently distinct from those caused by other viruses (1, 5, 6, 14, 21, 28). Moreover, the reaction of certain host plants kept at 18-20° C. and a 16-hour day toward inoculation with the yellow strain was markedly different from the response toward other virus X strains.

[1]Accepted for publication August 11, 1958.

[2]University of Wisconsin, Department of Plant Pathology; on leave of absence from Max Planck Institut fur Zuchtungsforschung, Koln-Vogelsang, German Federal Republic. Now at: Instituto Interamericana, Cacao Center, Turrialba, Costa Rica.

[3]University of Wisconsin, Department of Plant Pathology, and Crops Research Division, ARS, USDA, Madison, Wis.

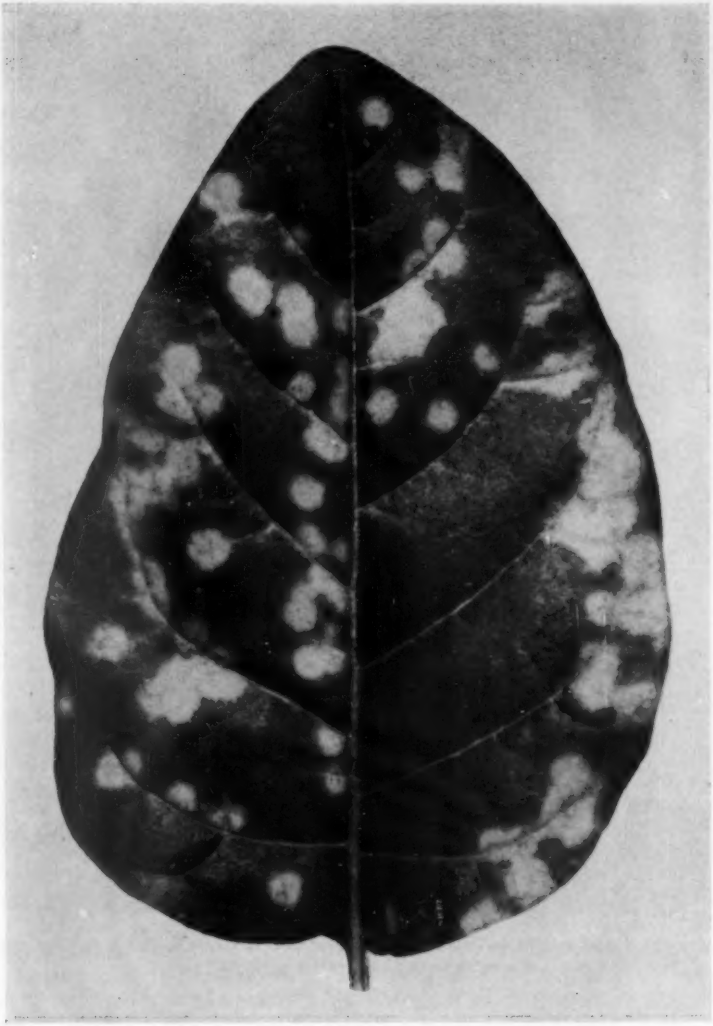


FIGURE 1.—Bright yellow non-necrotic lesions incited by the yellow strain of virus X on an inoculated leaf of *N. rustica* 17 days after inoculation.

After inoculation of the lower leaves, the yellow strain could be recovered from the non-inoculated upper leaves of *Cyphomandra betacea* Sendt., which is a deviation from the behavior of other mild strains tested by Matthews (18) and Thomson (25), who found that only the severe strain became generally systemic on this host.

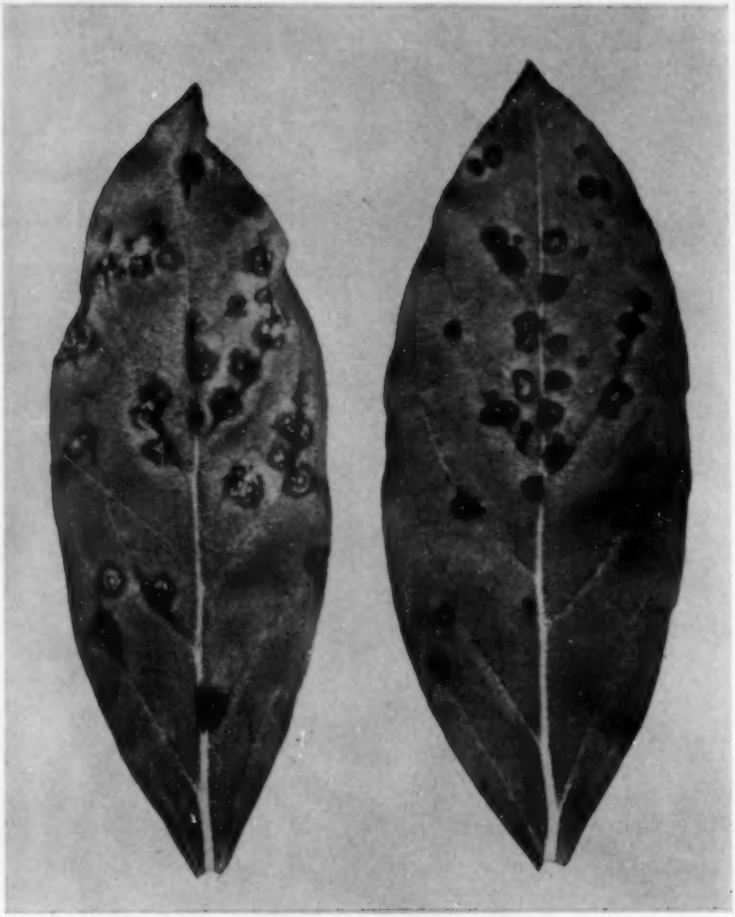


FIGURE 2.—Local lesions incited by a normal strain of virus X (left) and the yellow strain (right) on *G. globosa*.

On *Datura stramonium* L., and *Datura tatula* L., no symptoms appeared on the inoculated leaves, but within 4-6 days a barely visible veinclearing of the smallest veins of non-inoculated leaves resulted from systemic infection.

On *Nicotiana debneyi* Domin. the yellow strain became systemic and incited a severe mottle which, after 10 days, became necrotic. A similar systemic mottle on *N. clevelandii* Gray. did not develop into a necrotic type.

Throughout the investigation, the yellow strain was frequently trans-

ferred to normal (leaf size over 100 cm²) *N. tabacum* L. plants, where it failed to cause symptoms or systemic infection. This is in contradiction to the behavior of all other known virus X strains. On the mature (leaf area over 103 cm²) inoculated leaves of *N. rustica*, the yellow lesions expanded slowly along the veins, in a pattern similar to the brownspot strain (12), but the virus was not recovered from the uninoculated leaves of these plants.

In order to test the movement of the virus in very young plants, 15 seedlings each of *N. tabacum*, *N. rustica* and *N. glutinosa* L. were inoculated at the three-leaf stage (leaf area under 2 cm²) with the yellow strain. After 24 days, none of the *N. tabacum* and none of the *N. glutinosa* plants displayed any symptoms, whereas some expanding yellow lesions had appeared on the 4th and 5th leaf of 5 *N. rustica* plants. Five plants of *N. glutinosa* that were held in the greenhouse showed a slight mottle on all leaves after 50 days, while the *N. tabacum* and *N. rustica* plants remained symptomless. Simultaneous separate transfers to *G. globosa* from the inoculated leaves and the tops (8th to 10th leaf) of the 15 plants of each species revealed the presence of the yellow strain in all inocuated leaves, and in the tops of all *N. glutinosa*, of 1 *N. tabacum* and none of the *N. rustica* plants. Transfers from the *N. rustica* leaves showing yellow lesions proved the presence of the virus wherever symptoms had occurred.

The yellow strain was recovered from the inoculated symptomless leaves of *Vigna sinensis* (L.) Endl. held at 16° C., 20° C., and 24° C. The brownspot and the mottle strains, however, were reisolated only from *V. sinensis* plants held at 20° C. (11).

The thermal inactivation point of the yellow strain was compared with that of a mottle and a brownspot strain. Four replicates of 1 ml. of expressed crude sap were heated for 10 minutes at 66, 68, 70, 72, 74, and 76° C. in small glass tubes which were sealed at the lower end. Immediately after the treatment, the sap was cooled and transferred to leaves of *N. rustica* and *G. globosa*. The number of lesions incited by the brownspot and yellow strains after treatment at 66° C. was approximately equal to the number of lesions incited by the untreated controls, whereas heating to 68° C. decreased the lesion number for both strains to approximately 10 per cent of the controls. After treatment at 70° C., no lesions appeared with either strain. The mottle strain survived heating at 72° C. without significant decrease in lesion number. It incited a few lesions when heated to 74° C., but did not survive treatment at 76° C.

In order to corroborate further the identity of the yellow strain, 2 cross protection tests were carried out. Sixty young *D. tatula* plants were inoculated with the yellow strain and held for 30 days, after which the inoculated and the systemically invaded leaves of groups of 20 plants were each reinoculated with the mottle, the brownspot, and the ringspot strain. After 7 days, 1 plant in the brownspot and 1 plant in the mottle group developed some mosaic symptoms, while all others showed only the slight yellow-strain symptoms. Check transfers (as suggested by Sadavisan (23)) with diluted sap from the 2 deviating plants revealed 3 brown spots among many yellow lesions from the first plant. The transfer from the second plant and from those showing yellow strain symptoms incited only the typical yellow lesions on *N. rustica*. A similar test was carried out with the mottle strain as first inoculum. In this series, how-

ever, there was an interval of 23 days between the first and the challenge inoculations. All plants developed the typical mottle symptoms only, and subinoculations to *N. rustica* revealed only mottle lesions. The cross protection reactions indicate a close relationship between the yellow strain on one side and the mottle, the brownspot, and the ringspot strain on the other side.

It has been shown previously that virus X can pass through stem sections of the immune USDA Seedling 41956 grafted between infected scions and a healthy stock (3, 8, 10) and that the virus can be recovered from the roots of this seedling and the immune variety Saco after approach graft (4). In the present studies, the yellow strain passed in a similar manner through stem sections of both Saco and the USDA Seedling 41956. It could be recovered in some cases from the roots of these immune potatoes after top graft with infected D. tatula. The strain did not change in any detectable way during these passages.

In order to test the serological activity, the yellow strain was purified from systemically infected Samsun tobacco by freezing and differential centrifugation (30 minutes at 4000 rpm. and 70 minutes at 30,000 rpm.). The virus preparation was injected into a rabbit in 7 doses of 2 ml. each at 3-day intervals.

Ten days after the last injection, the rabbit was bled and, in order to remove host specific antibodies, the antiserum was incubated at 20° C. for 12 hours with 3 parts normal plant sap. After centrifugation (20 minutes at 3000 rpm) the antiserum was stored at 4° C. The antiserum reacted positively with sap of plants infected with the yellow, brownspot, mottle, and ringspot strains respectively, which had been centrifuged at 3000 rpm for 20 minutes. It did not react with healthy tobacco sap or that of plants infeceted with tobacco mosaic.

Mixtures of sap containing each of the brownspot, mottle, and ringspot strains with that containing the yellow strain were incubated at 37° C. for 1 hour with antiserum against the yellow strain in alpha optimum dilution (19), centrifuged and inoculated to *N. rustica*. The decrease in infectivity, as revealed by the number of lesions caused by the different strains, showed a definite specificity of the yellow antiserum toward the yellow strain.

An attempt was made to classify the yellow strain on the basis of the reaction of certain potato varieties. Cockerham (9), Cadman (7), and Ross and Koehler (15, 22) have shown that strains of virus X can be separated into 2 groups by the reaction of potato test varieties after graft inoculation. Certain varieties, such as Epicure, which carry the Nx gene, reacted top necrotically on graft inoculation with the normal strains of virus X, which is an indication of the hypersensitivity type of resistance. Other varieties, like Arran Victory, carried the Nb gene and reacted with top necrosis to the "B" (X^E) strains of virus X.

Five plants each of the varieties Arran Victory (nxNb), Katahdin (nxNb), Epicure (Nxnb), King Edward (Nxnb), Craigs Defiance (NxNb), and Kennebec (nxnb) were grafted with healthy *D. tatula* scions. These scions were then inoculated with the yellow strain. After 6 weeks, the side shoots that had appeared from the potato stocks were assayed. All Craigs Defiance shoots were dead, and all the Kennebec shoots remained

healthy. The King Edward plants developed top necrosis, whereas the Epicure plants remained healthy. Arran Victory showed top necrosis only on 2 plants. There was no reaction on Katahdin. On the basis of the above reactions, the yellow strain cannot be classified as to its "normal" or "B" character. The top necrotic reaction of King Edward would indicate that it belongs to the "B" group, which is contradicted by the lack of response in Epicure, and by the partly necrotic reaction in Arran Victory.

After the original recovery of the yellow strain from the virus X 8 infected Green Mountain tuber (11), strains inducing similar symptoms on *N. rustica* were recovered from the German virus X isolates Fortuna, King Edward, and Ro 7, as well as from the isolates AST 1 and AST 4 from New Zealand. Yellow strain symptoms on *N. rustica* were also observed after sap transfer from the varieties Chippewa (USA), Bismark (Australia), and Marta, Elsa, and Flava (Germany).

On the basis of symptoms on *N. rustica*, 3 strain groups of potato virus X have been distinguished; namely, the ringspot, the mottle and the brownspot group (6). It seems justifiable to add the newly discovered yellow strain as a fourth group. Reaction on *G. globosa*, serological relationship, cross protection, and the reactions of potato test varieties identify it as a strain of potato virus X, while symptoms on *N. rustica* and lack of symptoms on the inoculated leaves of *N. tabacum* and *D. tatula* distinguish it sufficiently from previously reported strains. The X^H strain of Salaman (24), to which it seems to bear the closest symptom relationship, incited top necrosis in Epicure after graft inoculation and became systemic in *N. tabacum*, which the new yellow strain did not. Salaman obtained strain X^H in apparently uncontaminated form from the variety Up to Date, while in the present work, subinoculations from this variety revealed no yellow symptoms. An isolate received from Canada under the designation X^H was essentially a mild mottle strain with ringspot contamination. Putnam's yellow strain (20) from the variety President was described as inciting quite different symptoms on *N. rustica*, and as causing a yellow mottle on *N. tabacum* and *D. stramonium*. Therefore, it cannot be considered similar to the present yellow strain. The virus X^y strain described by Bawden *et al.* (2) as causing "a bright yellow interveinal mosaic with little or no necrosis" on *N. glutinosa*, *N. tabacum*, and *D. stramonium* is also obviously a different type.

Summary

The isolation of a previously undescribed yellow strain of potato virus X is reported. The strain incites bright yellow non-necrotic lesions on the inoculated leaves of *N. rustica*. On certain other hosts, it also reacts differently from previously described virus X strains. The reaction of certain potato test varieties, the thermal inactivation point, the passage through stem sections of the immune variety Saco and USDA Seedling 41956, and some serological and cross protection relationships are described. It is concluded that the yellow strain is sufficiently different from other reported strains of potato virus X to warrant a separate designation.

Literature Cited

1. Anonymous. 1957. Plantesygdomme i Danmark 1954. Tidsskr. Planteavl. 60: 553-611.
2. Bawden, F. C., B. Kassanis, and F. M. Roberts. 1948. Studies on the importance and control of potato virus X. Ann. Appl. Biol. 35: 250-257.
3. ———— and F. M. L. Sheffield. 1944. The relations of some viruses causing necrotic diseases of the potato. Ann. Appl. Biol. 31: 33-40.
4. Benson, A. P. and W. J. Hooker. 1957. Recovery of virus X from "immune" potato varieties (*Solanum tuberosum* L.) Potato Assoc. Amer., Abstr., 41st Ann. Meeting.
5. Brierley, P. 1956. Susceptibility of *Gomphrena* to tomato ringspot virus. Pl. Dis. Reptr. 40: 667.
6. ———— and P. Lorentz. 1957. Hydrangea ringspot virus, the probable cause of "running-out" of the florists hydrangea. Phytopath. 47: 39-43.
7. Cadman, C. H. 1942. Autotetraploid inheritance in the potato: some new evidence. Jour. Genet. 44: 33-52.
8. Clinch, Phyllis E. M. 1942. The identity of the top necrosis virus in Up to Date potato. Proc. Roy. Soc. (Dublin) N.S. 23: 18-34.
9. Cockerham, G. 1943. The reactions of potato varieties to viruses X, A, B, and C. Ann. Appl. Biol. 30: 338-344.
10. Dykstra, T. P. 1939. A study of viruses infecting European and American varieties of the potato, *Solanum tuberosum*. Phytopath. 29: 40-67.
11. Hansen, A. J. 1958. A comparison of methods for inducing mutations in potato virus X. Ph.D. Thesis. Univ. of Wis.
12. ———— and R. H. Larson. 1957. The occurrence of the brownspot strain of potato virus X. Amer. Potato Jour. 34: 6-9.
13. Hoyman, W. G. 1951. A method of indexing potato virus X by use of petiole or tuber juice. Amer. Potato Jour. 28: 713-721.
14. Köhler, E. 1953. *Gomphrena globosa* als Wirtspflanze verschiedener Mosaikviren. Nachrbl. deut. Pflanzenschutzdienst (Braunschweig) 5: 21-22.
15. ———— and H. Ross. 1951. Das Verhalten deutscher Kartoffelsorten gegenueber verschiedenen Staemmen des X Virus im Pfropfversuch. 1. Mitt. Zuechter 21: 178-185.
16. Ladeburg, R. C., R. H. Larson, and J. C. Walker. 1950. Origin, interrelation and properties of ringspot strains of virus X in American potato varieties. Wis. Univ. Agr. Exp. Sta. Res. Bull. 195. 47 pp.
17. Larson, R. H., M. A. Stahmann, and J. C. Walker. 1954. The induction of mutants in potato virus X by nitrogen mustard. Proc. 2nd Conf. Pot. Vir. Dis. Wageningen 1954.
18. Matthews, R. E. F. 1949. Reactions of *Cyphomandra betacea* to strains of potato virus X. Parasit. 39: 241-243.
19. ————. 1957. Plant virus serology. Univ. Press, Cambridge. 128 pp.
20. Putnam, D. F. 1937. Comparative studies in potato virus diseases. Can. Jour. Res., C. 15: 87-103.
21. Quantz, L. 1956. Eine fuer Deutschland neue Viruskrankheit der Gartenbohne durch ein Tabaknekrose-Virus. Nachrbl. deut. Pflanzenschutzdienst (Braunschweig) 8: 7-8.
22. Ross, H. and E. Köhler. 1953. Das Verhalten deutscher Kartoffelsorten gegenueber verschiedenen Staemmen des X Virus im Pfopfversuch. 2. Mitt. Zuech. 23: 72-86.
23. Sadasivan, T. S. 1940. A quantitative study of the interaction of viruses in plants. Ann. Appl. Biol. 27: 359-367.
24. Salaman, R. N. 1938. The potato virus "X": Its strains and reactions. Phil. Trans. Roy. Soc. London, Ser. B. 229: 137-217.
25. Thomson, A. D. 1956. Definition of potato virus X strains present in New Zealand potato varieties. Austral. Jour. Agr. Res. 7: 527-535.
26. Timian, R. G., W. J. Hooker, and C. E. Peterson. 1955. Immunity to virus X in potato: studies of clonal lines. Phytopath. 45: 313-319.
27. ————, ————, and ————. 1955. Immunity to virus X in potato: studies of segregating seedling populations. Phytopath. 45: 445-450.
28. Wetter, C. and J. Brandes. 1956. Untersuchungen ueber das Kartoffel-S-Virus. Phytopath. Z. 26: 81-92.

THE INFLUENCE OF SPECIFIC GRAVITY AND CHEMICAL COMPOSITION ON HARDNESS OF POTATO TUBERS AFTER COOKING[1,2]

M. K. SHARMA, D. R. ISLEIB AND S. T. DEXTER[3]

INTRODUCTION

The meaning of the term "cooking quality" of potatoes is elusive and compounded of many factors. Well graded potatoes may cook mealy and white but still be unsatisfactory for table use because of slow or non-uniform speed of cooking. Most characteristically, the outer portion of certain tubers in a lot may cook readily while the inner portion remains uncooked. A few such hard-centered tubers can cause an objectionable texture in an entire batch of mashed potatoes. Apparently this problem has wide distribution.

No reports relating specifically to the problem of slow cooking have been found. The present paper reports studies of the effect of length and temperature of storage on the slow-cookng condition, and studies of the changes in pectins, hemicellulose and cellulose in the cell walls as tubers or tuber areas changed with respect to speed of cooking.

REVIEW OF LITERATURE

The Mechanism of Cooking. Knowledge of the changes which occur during cooking is incomplete and experimental results have often been contradictory. Day (5), on examination of cooked potatoes, found no breakage of the cell walls. The middle lamellae had dissolved and the cells were separated. She did not find that bursting of cells was associated with mealiness. Sweetman(20) agreed with Day, and suggested that the cooking process was characterized by such physico-chemical changes as partial gelatinization of the starch, the solution of some of the pectic substances, the increased digestibility of cellulose, the coagulation of most of the protein and more or less caramelization of the sugars.

Reeve (17) concluded from a histological study that tissue softening, starch gelation and swelling, cell separation and cell wall distention and rupturing were interdependent changes caused by cooking. This was essentially in agreement with the conclusion of Personius and Sharp (12, 13, 14) that neither failure of cell cohesion nor starch gelation, alone or in combination, was a causal factor for cooked texture in potatoes, but rather both were mechanisms of structural changes. Roberts and Proctor (18) discovered that in an aqueous medium, the middle lamellae of the parenchymatous starch-containing cells of the potato tuber were altered at 55°-60° C. and pectin substances in the walls were altered at 70° C. The cellulose of the walls was not destroyed at this temperature, but was so weakened that the walls were fractured and no longer retained the starch grains which had gelatinized and were released as a sticky mass.

[1]Accepted for publication August 22, 1958.
[2]Journal Article Number 2306, Michigan Agricultural Experiment Station, East Lansing, Mich.
[3]Formerly Graduate Research Assistant, Assistant Professor, and Professor, Department of Farm Crops, Michigan State University, East Lansing, Mich.

Variation in Cooking of Different Tuber Areas. Several investigators have reported that tuber regions of low starch content cook softer than those containing more starch. Sweetman and Lancaster (22) indicated that the firmness of cooked potatoes varied between different points on the same slice, and that bud ends cooked to a much softer stage than stem ends. Barmore (1) found a marked inverse relationship between ease in penetration after cooking and starch content. Thus, in cooked tubers of high starch content, penetration was low and softening on cooking less pronounced than in tubers of low starch content.

Thiessen (23) also found differences in a single tuber after two-centimeter thick sections had been cooked for various time priods. In most of the tubers the cortex remained harder than other areas and the stem end was harder than the bud end, with some abnormal tubers in each of the lots tested.

Pectin Constituents as Related to Potato Texture. Coudon and Bussard (4), Sweetman (21), and Barmore (1) found no significant relation between pectin content and mealiness of tubers. Freeman and Ritchie (7) offered additional evidence that the solution and disintegration of pectin material did not determine mealiness in potatoes. Bettelheim and Sterling (2) observed no direct relationship between various pectin fractions and texture of different varieties of potatoes. Recently Potter and McComb (15) showed very little difference in pectin content between different varieties. Pectin content was independent of the specific gravity of the tubers and varied with different growing locations and cultural conditions. There was no correlation between subjective appraisal for texture and the pectin content of the potatoes.

Personius and Sharp (13) explained the decrease in cell adhesion after cooking by a weakening of intercellular cementing material of potato tissue. Pyke and Johnson (16) demonstrated that soluble pectin readily dissolved in cold water and protopectin became rapidly soluble in water at 85° C. (185° F.). The calcium pectate content of potato decreased continuously during boiling in pure water or more rapidly in salt water indicating that these cementing materials were rapidly dissolved, permitting segments of potato tissue to break away.

In an attempt to explain the shrinkage which occurred in storage pectic changes in seed potatoes were examined by Dastur and Agnihotri (6). Their results showed a progressive increase in the soluble pectic fraction and the total pectic substance indicating a continuous formation of pectic substances during growth. During storage, free soluble pectin was formed at the expense of protopectin and middle lamella pectin.

Experimental Procedure

Specific Gravity Separation, Storage, Cooking and Pressure Testing of Katahdin Potatoes. Katahdin tubers were taken from cold storage in December and separated into three specific gravity groups (1) 1.065-1.070, (2) 1.074-1.076, and (3) 1.080-1.085, by immersing in brine solutions of known specific gravity. Half of the tubers of each specific gravity group were returned to cold storage at 40°. The other half was stored at 70°..F. under conditions simulating kitchen storage. At eight weekly intervals

three potatoes of each specific gravity group and from each storage were cooked in boiling water for 15, 20, 25 and 30 minutes. After cooking they were peeled and tested for done-ness with a pressure resistance tester.

In this experiment five penetration measurements were made on both the surface (cortex) and internal area (pith) of each tuber. The pressure in grams necessary to force a penetrometer plunger 0.1596 cm. in diameter (0.02 $cm.^2$) into the potato tissue to a distance of 1.2 cm. was recorded.

Cooking Tests and Chemical Analysis of Onaway Tubers. During 1956 and 1957, 19 varieties were examined for the presence of hard-cooking tubers. In 1956 no unusually hard-cooking samples were discovered, but in 1957 about 80 per cent of all Onaway tubers in the experimental lot failed to cook to done-ness when boiled in water for 25 minutes. Cellulose, hemicullulose and different pectic fractions of the hard and soft cooking tubers were determined.

A large number of Onaway tubers were cut into halves and numbered. One half of each tuber was cooked in boiling water for 25 minutes and tested with the penetrometer. Twenty-five halves of tubers which cooked soft and twenty-five halves of tubers which cooked hard were used for chemical analysis. The center-most portion of each raw tuber was cut into small pieces and the pieces composited. Twelve 20-gram samples were drawn from the composite of hard-cooking tubers and 12 from the soft-cooking tubers. One half of the samples from each group were used for the cellulose and hemicellulose analysis, and the remainder were used for the determination of pectins.

It had been observed that the characteristic of hard cooking disappeared after storage at room temperature. A number of Onaway tubers were quartered and each piece numbered. Quarters from hard cooking tubers were stored at 70 °F. in cellophane bags and 20 pieces were cooked at weekly intervals over a six-week period. Corresponding samples were analyzed for cellulose, hemicellulose and pectin fractions.

The procedure of Norris and Preece (11) was used for the determination of cellulose and hemicelluloses. Samples were blended in distilled water for one minute in a Waring blender. After transfer to a 250 ml. beaker the volume was brought to approximately 100 ml. and the samples heated to gelatinize the starch which was then hydrolyzed enzymatically. After complete hydrolysis of the starch the residues were separated by centrifuging, washed, and extracted several times to remove sugars and water soluble pectin. Subsequent steps followed the precedure of Norris and Preece.

The method used to isolate the pectins and separate them into water-soluble, 0.5 per cent ammonium oxalate-soluble and hot 0.05 N HCL soluble fractions was that described by McCollock (9). The pectin-containing extracts were freed from contaminating starch by enzymatic hydrolysis before precipitation of the pectins.

Experimental Results

Effect of Storage at Two Temperatures, 40° and 70° F., on the Cooking of Katahdin Potatoes of Three Specific Gravity Groups. Although three tubers from each group and each storage environment were boiled

15, 20, 25 and 30 minutes, the data from the potatoes cooked for 25 minutes are presented because potatoes which were either slightly cooked or completely cooked did not give differential measurements by the pressure resistance tester method.

Table 1 indicates the resistance to pressure of surface and internal regions after cooking. The data show that during storage at either temperature, the resistance to pressure of surface and internal areas decreased in each of the three specific gravity groups. Initially, resistance to pressure of the internal area was greater than that of the surface area group, but at 70° a more rapid decrease occurred in the internal than in the surface area. In the low specific gravity group, the final penetrometer readings were almost identical. In the 1.074-1.076 group, the internal area cooked softer than the external area after eight weeks of storage, and in the high specific gravity group the internal area cooked softer than the external area after the sixth week. Unlike tubers stored at 70°, changes in potatoes stored at 40° were similar in all three specific gravity groups. Penetrometer readings were relatively constant for the first four weeks, but as the storage period increased beyond four weeks the resistance to pressure of both areas decreased. The decrease was more rapid in the internal than in the surface area so that at seven or eight weeks of storage the remaining differences were small, whereas in potatoes stored for the same period at 70° the inside cooked softer. Table 2 shows the means of the three specific gravity groups combined, which illustrate these changes.

Pectin Fractions, Cellulose and Hemicelluloses of Onaway Potatoes. Table 3 shows the differences in pectin fractions between hard and soft cooking tubers,, and the changes in pectins associated with changes in cooking characteristics resulting from eight weeks' storage at 70° F. Potatoes which cooked hard contained no water soluble pectin, but more oxalate and acid soluble pectins and hemicellulose than soft-cooking tubers. Initially hard-cooking tubers which cooked soft after storage showed an increase in water soluble pectin, and decreases in oxalate and acid soluble pectins and hemicellulose.

Discussion

The firmness of potatoes after cooking can readily be determined by the use of a penetrometer. The cooked and cooled starch forms a stiff mass, which has a relatively low resistance to penetration, depending upon the proportions of starch and water when uncomplicated by other factors. When cooked starch is held within cell walls that do not separate readily from each other, the resistance to penetration may be many times that of the starch gel itself. Minimum pressures for cooked potatoes high in starch in this experiment were 40 to 60 grams, and for those low in starch were 20 to 30 grams. Pressure resistance of tubers which remained hard after normal cooking was 100 to 300 grams. Any pressure above 80 grams indicated an uncooked texture despite complete gelatinization of starch.

The hard cooking characteristic in Katahdin potatoes was found to be associated with different zones within tubers, with the temperature and duration of storage, and with specific gravity of the tubers. Initially, internal portions of these potatoes cooked more slowly than the external portions. Pressure resistance of centers fell more rapidly and to lower final

TABLE 1.—*Penetration resistance after cooking in grams per 0.02 cm² of Katahdin potato tubers of three specific gravity groups stored for different time periods at 40° and 70° F.**

Specific Gravity Group	Weeks in Storage	Stored at 40° F.		Stored at 70° F.	
		Surface Area	Internal Area	Surface Area	Internal Area
1.065-1.070	0	72.6	90.3	72.6	90.3
	1	76.8	95.2	61.3	74.5
	2	74.3	87.4	63.2	71.5
	3	78.5	90.2	55.2	65.0
	4	80.1	89.1	57.6	63.3
	5	70.4	89.1	53.2	60.4
	6	55.3	68.3	42.1	46.6
	7	52.2	58.7	39.4	40.6
	8	49.3	53.4	32.4	34.3
1.074-1.076	0	82.8	106.4	82.8	106.4
	1	85.2	108.7	74.4	83.2
	2	88.2	111.3	66.8	79.4
	3	85.4	106.1	58.4	78.7
	4	85.4	110.1	60.4	74.8
	5	78.4	95.4	61.3	66.3
	6	64.2	79.6	55.0	58.7
	7	60.3	70.8	45.2	43.1
	8	58.2	67.3	38.7	21.2
1.080-1.085	0	83.2	106.9	83.2	106.9
	1	80.4	110.0	64.8	87.4
	2	89.1	109.1	68.6	81.4
	3	81.6	110.4	57.0	82.8
	4	77.6	112.0	62.8	77.4
	5	72.6	98.3	59.3	55.8
	6	52.1	70.0	52.6	39.5
	7	51.8	64.3	50.1	25.5
	8	46.1	63.2	47.3	17.0

*Means of 15 penetrometer measurements, five from surface and five from internal areas of each of three tubers.

TABLE 2.—*Penetration resistance in grams per 0.02 cm² of Katahdin potato (means of three specific gravity groups) from 40° and 70° F. storage, after cooking at weekly intervals.**

Weeks in Storage	Stored at 40° F.		Stored at 70° F.	
	Surface Area	Internal Area	Surface Area	Internal Area
0	79.5	101.2	79.5	101.2
1	80.8	104.6	66.8	81.7
2	83.9	102.6	66.2	77.4
3	81.8	102.2	56.9	75.5
4	80.0	103.7	60.3	71.8
5	73.8	94.3	57.9	60.8
6	57.2	72.6	49.9	48.3
7	54.8	64.6	44.9	36.4
8	51.2	61.3	39.5	24.2

*Means of 45 penetration measurements, five from surface and five from internal area of nine tubers.

TABLE 3.—*Percentage fresh weight of three pectic fractions, cellulose and hemicellulose of Onaway tubers before and after storage.*

	Water Soluble Pectin	NH_4-oxalate Soluble Pectin	Acid Soluble Pectin	Cellulose	Hemicell. (incl. acid-sol pectin)	Hemicell. (Minus acid-sol pectin)
Hard Cookers Before Storage	0.0	0.5781 ±0.018*	0.8384 ±0.015	0.4186 ±0.012	2.7056 ±0.029	1.8671 ±0.010
Soft Cookers Before Storage	0.0578 ±0.002	0.3111 ±0.002	0.4003 ±0.002	0.4824 ±0.001	1.4435 ±0.04	1.0431 ±0.14
Hard Cookers After Storage, Having Become Soft	0.1345 ±0.057	0.3784 ±0.011	0.5114 ±0.024	0.4306 ±0.022	1.8001 ±0.045	1.2887 ±0.025

*Standard error of the mean of six determinations.

levels than that of external areas in 70° F. storage and in high specific gravity samples. In 40° F. storage, changes in hardness of internal and external tissues were more nearly alike, so that these two areas were approximately equal in pressure resistance after eight weeks' storage.

Considerable data from other samples used in an earlier phase of this study by Sharma, Isleib and Dexter (19) showed a consistent pattern for dry matter distribution with relation to specific gravity of the total tuber. If penetration resistance were simply a function of starch concentration, exterior tuber areas would regularly show greater hardness than interior portions. This was not found to be the case, except after considerable time in storage at 70° F., which led to the conclusion that some factor other than starch content was responsible for penetration resistance of tubers prior to prolonged or warm storage. The disappearance of such a factor, which could be insoluble pectins, would account for the final condition in which specific gravity and hardness were found in association. A change in pectins could be expected to occur faster at 70° F. than at 40° F., as the changes in pressure resistance were seen to do.

At the end of the experiment on Katahdin tubers, it was not possible to embark on analytical work on these potatoes as they had been cooked and discarded. A sample of Onaway potatoes had the desired hardness after cooking, and was used for the pectin and hemicellulose analysis. The analytical data confirmed the postulation of a factor other than specific gravity association with hardness in cold storage, as high levels of water-insoluble pectins and hemicellulose were present in Onaway tubers which cooked hard. As pressure resistance after cooking decreased, these tuber constituents partially disappeared.

Bonner (3) stated that during the development of fruit, protopectin is laid down in the primary walls and in many cases accumulates to a high

concentration, particularly in apple, pear and citrus species. Middle lamella pectate is likewise accumulated in the fruit. Norman (10) in his review of cellulose and related cell wall compounds, stated that the middle lamella of plant tissue is believed to be insoluble calcium pectate whereas the cell wall pectic substances are protopectin and soluble pectin. The protopectin is always found closely associated with other cell wall constituents. Ippolito (8) found that when predominating pectic compounds are soluble or can be hydrolyzed, the tissue easily dissociates, becoming soft. With an excess of cellulose and hemicelluloses the pectic compounds are not completely hydrolyzed and vegetables do not cook readily. An explanation of the observed cooking performance of hard cooking tubers incorporates these findings.

The changes in Onaway tubers after storage may be attributed to the observed decomposition of calcium pectate, protopectin and hemicelluloses, with a consequent decrease in cell wall rigidity due to alteration in their thickness and firmness and of the cementing substances of the middle lamella. These changes had a pronounced effect on the force required to push the cells apart, as measured by firmness after cooking.

At the beginning of storage, hardness in cooking was mainly due to materials deposited in association with cellulose in the cell walls. After the hydrolysis of these substances, starch largely determined the penetration resistance after cooking. Sharma *et al.* (19) found greater differences between specific gravities of surface and internal areas in high specific gravity potatoes in contrast to low specific gravity potatoes. This is reflected by a greater difference in hardness between areas in tubers with high specific gravity caused by the large differences in the starch content between surface and internal areas. Many investigators (Sweetman and Lancaster, (22), Barmore (1), Thiessen (23), and others) have reported that the portions within a tuber which had a high starch content were firmer after cooking than those which had less starch.

At the end of storage the potatoes stored at 40° F. cooked similarly at the surface and internal areas. Apparently the insoluble pectic substances and hemicelluloses had not yet hydrolyzed to the extent that starch content alone rather than a combination of starch with cell-wall materials determined hardness after cooking.

Conclusions

1. Potatoes generally cook more slowly immediately after harest than after a period of storage. Degree of "done-ness" can be measured with a penetrometer.

2. In some cases, extremely slow cooking shortly after harvest is encountered in a considerable fraction of the tubers in a given lot, but this does not seem to be an invariable varietal characteristic.

3. A reduction in hardness after a standard cooking procedure is accomplished more rapidly in storage at 70° F. than at 40° F.

4. Tubers from certain varietal lots may be selected for either "hard" or "soft" cooking. Those that are hard to cook are characterized by a far higher content of insoluble pectins and hemicelluloses than those that cook soft. The cellulose contents are found to be about the same in all tubers.

5. Storage reduces the difficulty of cooking and also reduces the content of insoluble pectins and hemicelluloses.

6. Tubers or parts of tubers with high specific gravity are firmer after cooking than are those with a low specific gravity.

7. Before storage, the effect of the high levels of insoluble pectin and hemicelluloses in the cell walls, which prevents their easy separation, may completely mask any starch gel effect on hardness. This cell-wall effect may easily be 10 times the starch-gel effect.

Literature Cited

1. Barmore, M. A. 1937. Potato mealiness and changes in softness in cooking. Food Res. 2: 377-385.
2. Bettelheim, F. A. and C. Sterling. 1955. Factors associated with potato texture. II. Pectic substances. Food Res. 20: 118-129.
3. Bonner, J. 1952. Plant Biochemistry. New York: Academic Press, Inc.
4. Coudon, H. and L. Bussard. 1897. Recherches sur la pomme de terre alimentaire. Ann. Sci. Agron. 2e ser. 1: 250-291.
5. Day, E. D. 1909. The effect of cooking on cellulose. Jour. Home Econ. 1: 177.
6. Dastur, R. H. and S. D. Agnihotri. 1934. Study of the pectic changes in potato tuber at different stages of growth and in storage. Indian Jour. Agri. Sci. 4: 430-450.
7. Freeman, M. E. and W. S. Ritchie. 1940. Pectins and the texture of cooked potatoes. Food Res. 5: 167-175.
8. Ippolito, G. D. 1926. Causes determining cooking power of vegetables. Rass. Intern. Agri. 10-2, 994. (Chem. Abs. 22: 1413. 1928).
9. McColloch, R. J. 1925. Determination of pectic substances and pectic enzymes in citrus and tomato products. U. S. Dept. Agr. Fruit and Veg. Che. Lab. Pasadena, Cal., A. I. C. 337.
10. Norman, A. G. 1937. The biochemistry of cellulose, the polyuronides, lignin, *etc.* Oxford Univ. Press, Oxford.
11. Norris, F. W. and I. A. Preece. 1930. Studise on hemicelluloses. 1. The hemicelluloses of wheat bran. Biochem. Jour. 24: 59-66.
12. Personius, C. J. and P. F. Sharp. 1938. Adhesion of potato-tuber cells as influenced by temperature. Food Res. 3: 513-524.
13. ———— and ————. 1939a. Adhesion of potato tissue cells as influenced by pectic solvents and precipitants. Food Res. 4: 299-307.
14. ———— and ————. 1939b. Stimulation, by chemical agents, of cooking of potato tissue. Food Res. 4: 469-473.
15. Potter, A. L. and E. A. McComb. 1957. Carbohydrate composition of potatoes. Pectin content. Amer. Potato Jour. 34: 342-346.
16. Pyke, W. E. and G. Johnson. 1940. The relation of the calcium ion to the sloughing of potatoes. Amer. Potato Jour. 17: 1-9.
17. Reeve, R. M. 1954. Histological survey of conditions influencing texture in potatoes. 1. Effects of heat treatment on structure. Food Res. 19: 323-332.
18. Roberts, E. A. and B. E. Proctor. 1955. The comparative effect of ionizing radiations and heat upon the starch containing cells of the potato tuber. Food Res. 20: 254-263.
19. Sharma, M. K., D. R. Isleib and S. T. Dexter. 1958. Specific gravity of different zones within the potato tuber. Amer. Potato Jour. 35: 784-788.
20. Sweetman, M. D. 1933. The physico-chemical changes produced by the cooking of potatoes. Amer. Potato Jour. 10: 169-173.
21. ————. 1936. Factors affecting the cooking quality of potatoes. Maine Agr. Exp. Sta. Bull. 383: 297-387.
22. ———— and M. C. Lancaster. 1931. Penetrometer measurement of "doneness" in cooked vegetables. Jour. Home Econ. 23: 565-567.
23. Thiessen, M. J. 1947. The culinary qualities and nutritive values of potatoes grown upon dry and irrigated land. Wyom. Agr. Exp. Sta. Bull. 280.

CALL FOR PAPERS

The 43rd Annual Meeting of the Potato Association of America will be held at the University of New Brunswick, Fredericton, Canada, August 13 through 15, 1959. Optional tours on August 12 and 16 will be arranged for visitors.

Please send titles of papers to be presented at this annual meeting to Robert V. Akeley, Crops Research Division, Plant Industry Station, Beltsville, Maryland, by May 15. Along with the title please include: (a) approximate time required to present your papers, (b) if an illustrated talk, the size of the slides to be used, and (c) the names and official addresses of the authors as you wish them to appear on the program. As has been our custom, we will again distribute mimeographed abstracts of these papers to members attending the annual meeting. These abstracts will be published in the American Potato Journal. Therefore, abstracts should accompany the titles of the papers. Abstracts should not exceed 250 words. Presentation of papers should not exceed 15 minutes, and the use of 2 x 2 slides is preferred.

We would like to receive good papers concerned with problems in potato breeding, diseases, production, quality, nutrition, storage, transportation, and marketing. We expect to have at least one session devoted to invitational papers presented by European research workers.

Your cooperation in sending the titles and abstracts as early as possible will aid in the mimeographing of these abstracts and the prompt preparation and printing of programs. Titles and abstracts received after our deadline of May 15 may not be accepted. Please bring this notice to the attention of your students and colleagues.

R. V. AKELEY, *Secretary*

IT PAYS TO BE HIDDEN HUNGER CONSCIOUS

Plants, like people, can suffer from hidden hunger — the period between the time they are in good health and in bad health. This is an insidious time because nothing looks wrong. The plant seems to be healthy — or certainly shows no signs of hunger. And then — almost suddenly, it seems — the plant crosses a point of no return as far as its finest yield and quality are concerned. Outward signs may never show — except in the yield. It's an insidious thing. Hidden Hunger! A problem requiring careful diagnosis and management that is always hunger conscious.

AMERICAN POTASH INSTITUTE, INC.

SERVING AGRICULTURE FOR OVER TWO DECADES

1102 Sixteenth St., N. W. Washington 6, D. C.

Member Companies: American Potash & Chemical Corporation • Duval Sulphur & Potash Company • Potash Company of America • Southwest Potash Corporation • United States Potash Company Division of United States Borax & Chemical Corporation

DEPENDABLE

is the word for

ORCHARD BRAND SPRAYS & DUSTS

The right product for every pest problem

Insecticides

DDT
Parathion
Malathion
Aldrin
Dieldrin
Calcium Arsenate

Fungicides

Phygon-XL
Agri-Mycin* 100
"340" Spraycop®—(34% Neutral Copper)
"530" Spraycop—(53% Neutral Copper)

See your Orchard® Brand dealer soon!

Specialties

Genicop® Wettable Powder (25% DDT—69% Basic Copper Sulfate)
Sodium Arsenite Vine Killers
Maleic Hydrazide MH-30 Sprout Inhibitor

GENERAL CHEMICAL DIVISION

40 Rector Street, New York 6, N.Y.

Allied Chemical

*Reg. Trademark of Chas. Pfizer & Co.

Now . . . you can do what leading potato growers do to help keep their plants healthy all season long

USE

CHEM-BAM

with exclusive U-101 for protection against early and late blight

CHEM-BAM

For protecting plants against blight and other diseases. CHEM-BAM is the only liquid nabam fungicide with the exclusive U-101 chemical agent. U-101 makes CHEM-BAM stick to plants through rain and repeated waterings.

CHEM-BAM

For higher yields in every field. Healthier plants and bigger profits. You get increased yields and bigger profits because CHEM-BAM does a three-way job. CHEM-BAM spreads . . . CHEM BAM wets . . . CHEM-BAM sticks.

CHEM-BAM

For economy. CHEM-BAM mixes easily, evenly with water and most commonly used insecticides. You get even distribution throughout the entire sprayed area.

CHEM-BAM gives you the most for your money . .

- The most sticking quality
- The most yield in every field
- The most efficient control of early and late blight.

order CHEM-BAM from your local farm supply dealer today

CHEMICAL INSECTICIDE CORPORATION

30 WHITMAN AVENUE LIberty 9-2300 METUCHEN, N. J.

MAINE CERTIFIED SEED POTATOES

Are the Product of Maine's Complete Seed Program Which Includes —

1. Super foundation seed farm.
2. Planned increase of superior seed lots by foundation growers.
3. Roguing service for foundation growers.
4. Florida test for foundation seed.
5. Experienced seed inspectors working with 1500 seed growers.

Maine offers the seed buyer a wide choice of varieties (27 in 1958) and seed sizes to fill every need. Maine has an ideal program to provide for the increase of new varieties. Rapid increase of disease free stock is easily accomplished under this plan.

For list of Certified Seed Growers, write:

PAUL J. EASTMAN
Maine Department of Agriculture
Augusta,, Maine